Neutrino Factory and Muon Collider Collaboration R&D Program

Michael S. Zisman
CENTER FOR BEAM PHYSICS

Project Manager, Neutrino Factory and Muon Collider Collaboration

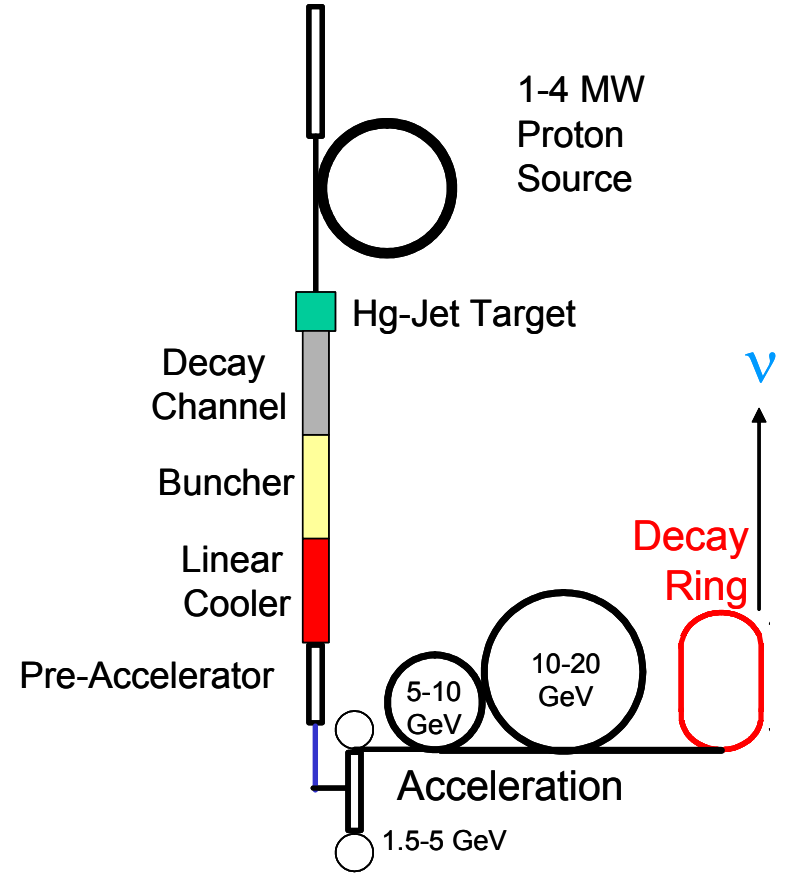
Advanced Accelerator R&D Subpanel Meeting—Fermilab
February 16, 2006

Outline

- Facility description
- Ionization cooling
- Physics context
- Organization
- Process
- History
- Training
- International perspective
- R&D overview
- R&D accomplishments (Simulations, Targetry, RF cavity, Absorber, SCRF, MICE)
- Future plans
- Summary and outlook

Facility Description

- Neutrino Factory comprises these sections (NFMCC doing R&D on most)
  - Proton Driver
    (primary beam on production target)
  - Target and Capture
    (create π's; capture into decay channel) $\Rightarrow$ MERIT
  - Bunching and Phase Rotation
    (reduce ΔE of bunch)
  - Cooling
    (reduce transverse emittance of beam) $\Rightarrow$ MICE
  - Acceleration
    (130 MeV $\rightarrow$ 20–50 GeV with RLAs or FFAGs)
  - Decay Ring
    (store muon beam for ≈500 turns; optimize yield with long straight section aimed in desired direction)

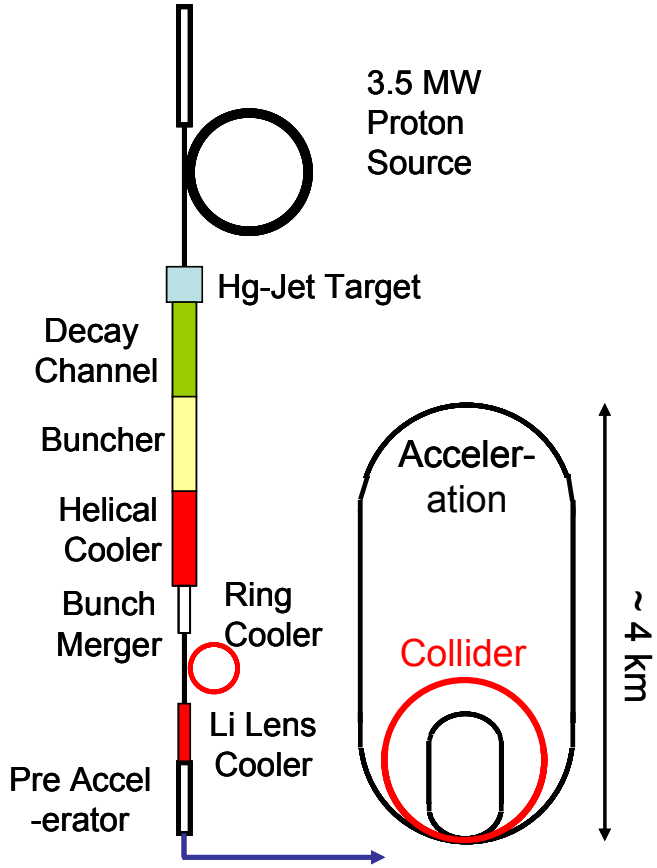


U.S. design (schematic)

- Not an easy project, but no fundamental problems found

Facility Description

- Muon Collider comprises these sections (similar to Neutrino Factory)
  - Proton Driver
    (primary beam on production target)
  - Target and Capture
    (create π's; capture into decay channel) $\Rightarrow$ MERIT
  - Phase Rotation
    (reduce ΔE of bunch)
  - Cooling
    (reduce longitudinal & transverse emittance of beam)
    $\Rightarrow$ MICE $\rightarrow$ MANX
  - Acceleration
    (130 MeV $\rightarrow$ 1.5 TeV with RLAs or FFAGs)
  - Collider Ring
    (store muon beam for ≈500 turns; 1 IP)



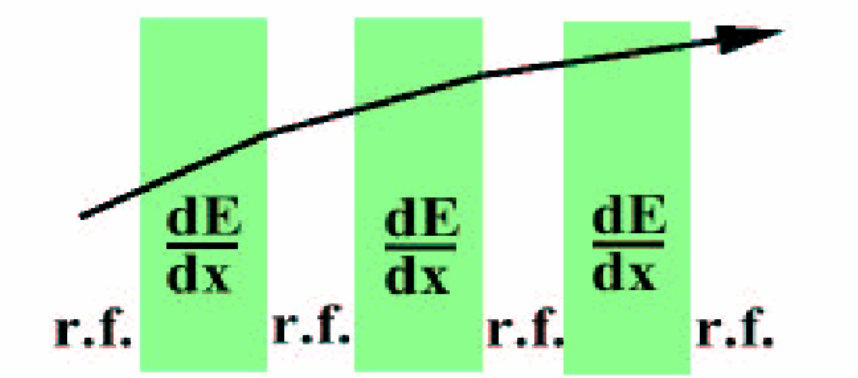
- Much of Muon Collider R&D is common with Neutrino Factory R&D

Facility Description

- Challenges of a muon-based facility (Neutrino Factory or Collider)
  - muons have short lifetime (2.2 μs at rest)
    - puts premium on rapid beam manipulations
      - high-gradient NCRF (in magnetic field) for cooling
      - presently untested ionization cooling technique
      - fast acceleration system
  - muons are created as tertiary beam ($p \rightarrow \pi \rightarrow \mu$)
    - low production rate $\Rightarrow$
      - target that can handle multi-MW beam
    - large muon beam transverse phase space and energy spread $\Rightarrow$
      - ionization cooling
      - high-acceptance acceleration system and decay ring
- Cooling requirements for Muon Collider much more stringent than for Neutrino Factory

Ionization Cooling

- Ionization cooling analogous to familiar SR damping process in electron storage rings
  - energy loss (SR or dE/dx) reduces p_x, p_y, p_z
  - energy gain (RF cavities) restores only p_z
  - repeating this reduces $p_{x,y}/p_z$ and thus transverse emittance



Ionization Cooling

- There is also a heating term
  - with SR it is quantum excitation
  - with ionization cooling it is multiple scattering
- Balance between heating and cooling gives equilibrium emittance

$$\frac{d\varepsilon_N}{ds} = -\frac{1}{\beta^2}\left|\frac{dE_\mu}{ds}\right|\frac{\varepsilon_N}{E_\mu} + \frac{\beta_\perp (0.014\,\mathrm{GeV})^2}{2\beta^3 E_\mu m_\mu X_0}$$

cooling heating

$$\varepsilon_{x,N,equil.} = \frac{\beta_\perp (0.014\,\mathrm{GeV})^2}{2\beta m_\mu X_0 \left|\frac{dE_\mu}{ds}\right|}$$

  - prefer low $\beta_\perp$ ($\Rightarrow$ strong focusing), large X_0 and dE/ds ($\Rightarrow$ H_2 is best)

Physics Context

- **NFMCC** focus on Neutrino Factory and Muon Collider driven by physics
  - for Neutrino Factory
    - exciting evidence for neutrino oscillations, with parameters within reach of future accelerator experiments
    - beam properties

$$\mu^+ \rightarrow e^+ \nu_e \overline{\nu}_\mu \Rightarrow 50\% \nu_e + 50\% \overline{\nu}_\mu$$

$$\mu^- \rightarrow e^- \overline{\nu}_e \nu_\mu \Rightarrow 50\% \overline{\nu}_e + 50\% \nu_\mu$$

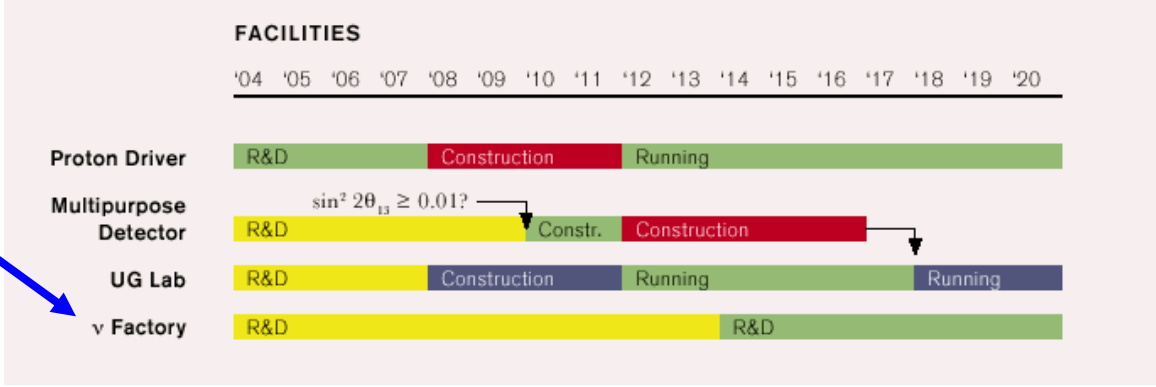
    - decay kinematics well known (minimal hadronic uncertainties in spectrum, flux, and comparison of μ^+ and μ^- results)
    - $\nu_e \rightarrow \nu_\mu$ oscillations give easily detectable "wrong-sign" muons
  - for Muon Collider
    - no bremsstrahlung or beamstrahlung; fits on existing site
    - 10x higher energy reach than similar energy proton collider

Physics Context

- **APS Neutrino Physics Study assumes that our program is ongoing**

> • *Research and development to assure the practical and timely realization of accelerator and detector technologies critical to the recommended program.* Of particular importance are R&D efforts aimed toward development of a high-intensity proton driver, a neutrino factory, a very large neutrino detector, and techniques for detection of ultra-high-energy neutrinos.

— **NFMCC R&D program is explicitly called out in timeline**



- **here, yellow is <$10M/yr and green is $10–40M/yr**

Organization

- U.S. Neutrino Factory and Muon Collider Collaboration broadly based
  - more than 100 scientists and engineers from about 30 institutions
- NFMCC is a mix of accelerator and particle physicists
  - from both National Labs and Universities
- We also greatly benefit from collaborators in Europe and Japan
- Main funding support from DOE, including valuable SBIR grants
  - some U.S. support has come from NSF
- Direct funding of our multi-institution R&D collaboration represented a paradigm shift for DOE
  - we believe it has been a key to our success

NOTE: NFMCC is an R&D organization, *not* a project team

When a Neutrino Factory or Muon Collider project is launched, a Lab (or Labs) will run it

Organization

- **NFMCC goals**
  - **collaboration governed by Charter* defining goals and organization**

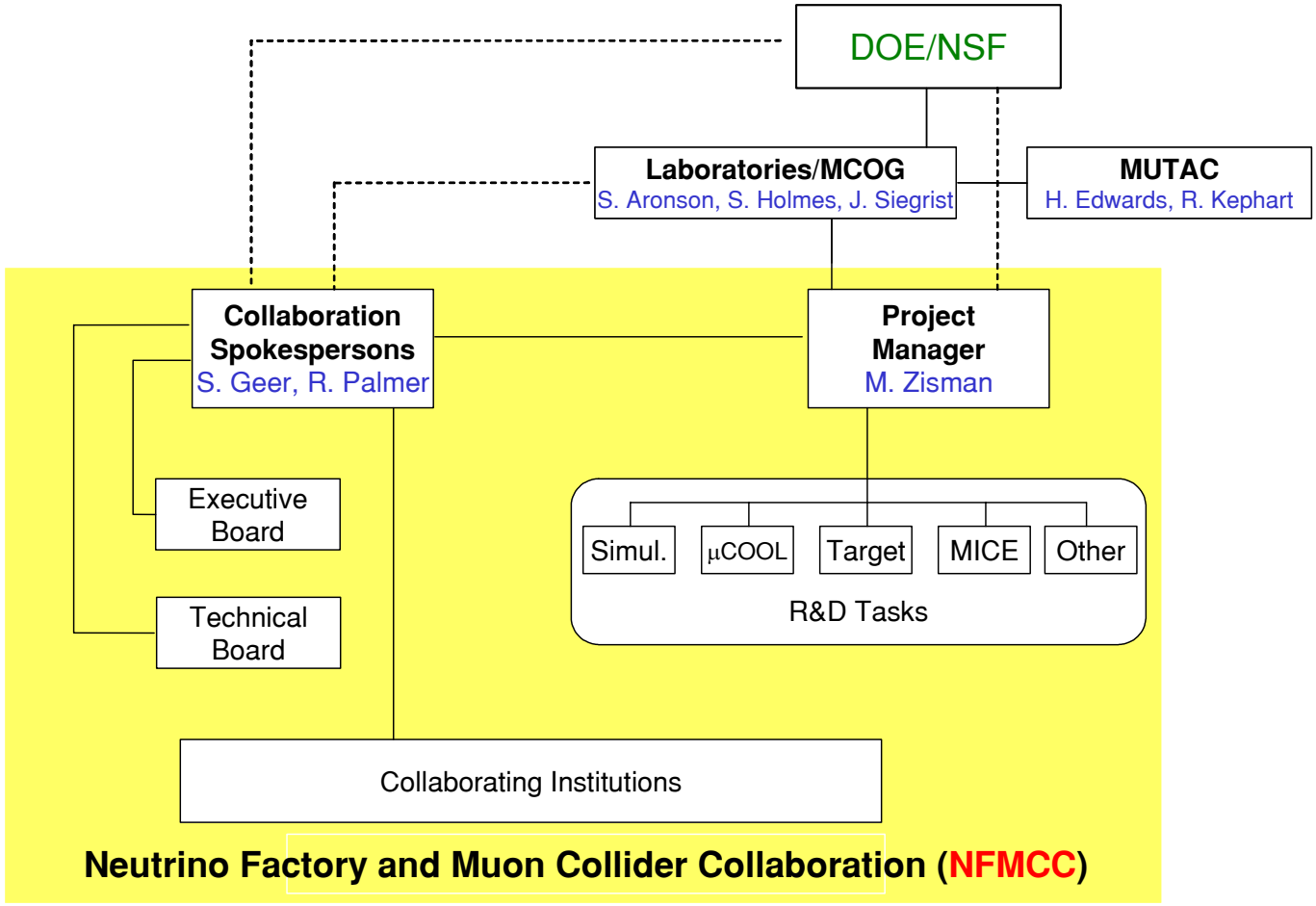
> *"The goal of this organization (referred to hereinafter as the Muon Collaboration) is to study and develop the theoretical tools, the software simulation tools, and to carry out R&D on the hardware that is unique to the design of neutrino factories and muon colliders. An important part of the program will be an extensive experimental program to verify the theoretical and simulation predictions and to gather the necessary data for a future facility."*

***see** http://www.cap.bnl.gov/mumu/info/MC_Charter_Final_020903.pdf

Shortened form of name no longer used;
MC → NFMCC

Organization

- NFMCC organization chart



Process

- Each year, R&D groups propose an annual program to the Technical Board, based on NFMCC budget guidance from DOE
- PM prepares budget based on this input
  - subsequently approved by Technical Board, Executive Board, and Co-Spokespersons
  - budgets determined by R&D program, not by "institutional commitments"
- After budget finalized, PM negotiates milestones with each institution based on the R&D plan
  - milestones specify dates and deliverables
    - a "report card" is generated at year's end to audit performance
- PM summarizes annual spending and accomplishments in a detailed report for MCOG and DOE at the end of each year
  - report also includes non-DOE information insofar as it is available

History

- NFMCC began as informal group of ≈100 people investigating feasibility of building a high-energy Muon Collider
  - see "Muon Collider Feasibility Study Report" Snowmass 1996 (BNL-52503, FNAL-Conf-96/092, LBNL-38946; 480 pages)
- Oversight/review structure initiated by DOE and Lab Directors when organization formalized
- First MUTAC review recommended that NFMCC focus on one facility and conduct end-to-end technical study
  - choice was Neutrino Factory (viewed as technically simpler)
- In 1999–2000, Fermilab director sponsored Feasibility Study I (~$1M engineering effort)
  - concluded that Neutrino Factory is feasible but expensive (~$2B)
- In 2000–2001, BNL director + NFMCC sponsored Feasibility Study II
  - intensity improvement (5x Study I), but still expensive

History

- **HEPAP Subpanel report in 2002 supportive of NFMCC effort**

  —motherhood statement on accelerator R&D

> *"We give such high priority to accelerator R&D because it is absolutely critical to the future of our field. … As particle physics becomes increasingly international, it is imperative that the United States participates broadly in the global R&D program."*

  — specific recommendation on NFMCC R&D program

> *"We support the decision to concentrate on intense neutrino sources, and recommend continued R&D near the present level of 8M$ per year. This level of support is well below what is required to make an aggressive attack on all of the technological problems on the path to a neutrino factory."*

This recommendation has not been realized to date

Training

- **NFMCC accelerator R&D provides excellent training opportunities for both accelerator physics and particle physics students**

Zachary Conway	LH2-absorber R&D	UIUC	Ph.D.
Vincent Wu	rf-cavity R&D	U. Cincinnati	Ph.D.
Jian Du	Magneto-hydrodynamics	Stony Brook	Ph.D.
Trung LePhuoc	Material studies	Stony Brook	Ph.D.
Adrian Fabich	Hg jet studies	Vienna Tech. U.	Ph.D.
HeeJin Park	Hg jet studies	Stony Brook	Ph.D. cand.
Alexey Poklonskiy	Neutrino factory design	MSU	Ph.D. cand.
Pavel Snopok	Neutrino factory design	MSU	Ph.D. cand.
Mohammad Alsharo'a	rf-cavity design	IIT	Ph.D. (ME)
Eyad Almasri	LH_2-absorber R&D	IIT	MS (ME)
Laura Bandura	LH_2-absorber R&D	NIU	MS
Michael Boghosian	LH_2-absorber R&D	IIT	MS (ME)
Donna Kubic	Thin-window R&D	NIU	MS
Jason Crnkovic	Cryogenic temp. meas.	UIUC	undergrad
Lauren Ducas	rf-cavity R&D	UIUC	undergrad
Stephanie Majewski	Thin-window R&D	UIUC	undergrad
Brooke Rankin	MICE Cherenkov	U.-Mississippi	undergrad
Hart Wilson	MICE simulation	IIT	undergrad

- **We would like to do even more!**

International Perspective

- International Neutrino Factory community has held annual "NuFact" workshops since 1999
  - provides opportunity for physics, detector, and accelerator groups to plan and coordinate R&D efforts at "grass roots" level
  - venue rotates among geographical regions (Europe, Japan, U.S.)

Year	Conference Venue
1999	Lyon, France
2000	Monterey, CA
2001	Tsukuba, Japan
2002	London, England
2003	New York, NY
2004	Osaka, Japan
2005	Frascati, Italy
2006	Irvine, CA

International Perspective

- Activities in Europe
  - European Neutrino Factory Feasibility Study completed in 2002
  - ECFA report encouraged R&D effort; EMCOG set up (Spring 2002)
  - Beams for European Neutrino Experiments launched in 2004 (Chair: Vittorio Palladino)
  - International Scoping Study (ISS) of Future Neutrino Factory and Superbeam Facility launched at NuFact05
    - hosted by RAL; sponsored by BENE, NFMCC, NuFact-J, UKNF
- Activities in Japan (KEK, Kyoto, Osaka)
  - Japanese Neutrino Factory Feasibility Study completed in 2001
  - contributing to NFMCC effort (absorbers and FFAG studies)
  - also to ISS
- Two "global" experiments launched (MICE, MERIT)

R&D Overview

- Since FY03, the NFMCC DOE budget has been nearly flat-flat
  - with Subpanel's help, hope to restore funding to FY01–FY02 level

Year	DOE-base ($M)	DOE-NFMCC ($M)	TOTAL ($M)
FY00	3.3	4.7	8.0
FY01	3.0	3.2	6.2
FY02	3.0	2.8	5.8
FY03	2.1	1.4	3.5
FY04	2.2	1.8[a)]	4.0
FY05	1.9	1.7	3.6
FY06	1.8	1.8	3.6

[a)] Includes $0.4M supplemental funds

- Helped by NSF funding for MICE, DOE-SBIR funding for Muons, Inc.
  - NSF operating level: $100K per year for FY05–07, plus FY06 MRI grant ($750K) for tracker detector electronics and spectrometer
- By juggling projects across fiscal year boundaries and careful prioritization, we continue to make progress...

  ⇒ international experiments have only schedule (not cost) contingency

R&D Overview

- **MUTAC and MCOG have been very supportive of our program**
  - **MUTAC stated:**

"The Committee notes the significant progress achieved in establishing a worldwide collaboration and the integration of the various R&D programs. In particular Japanese participation has increased in many areas such as MuCool, MICE, targetry, FFAG and NuFact workshops. The MICE proposal is an example of the effective operation of this larger collaboration."

"We note that muon accelerators (factories or colliders) are one of the very few HEP future accelerator ideas on the horizon, that R&D to develop these ideas and provide proof of principle takes years of consistent effort and support, and that major collaborative efforts and international commitments must have consistent support."

  - **MCOG stated:**

"...MCOG accepts and endorses the MUTAC Report attached here and urges the DOE to seek ways of supplementing R&D funding for the Muon Collaboration. An additional amount of $1M or more, per year, would provide important relief to the program and improve the rate of advance in the technical areas of study. We urge the DOE to consider such an increase in funding as they prepare future budgets for the muon R&D program."

More MUTAC/MCOG comments available in Appendix

R&D Overview

- NFMCC R&D program has the following components:
  - simulation and theory effort in support of Neutrino Factory and Muon Collider design
  - development of high-power target technology (Targetry)
  - hardware development of cooling channel components (MUCOOL)
- NFMCC also participates in three international endeavors:
  - MICE (ionization cooling demonstration)
  - MERIT (high-power Hg-jet target)
  - ISS (simulation studies of Neutrino Factory design)
- Hardware development continues as major focus of NFMCC activity
- Simulation effort aimed at reducing Neutrino Factory cost ("Study IIa") gave good results in APS neutrino study
  - increased performance, lower cost

R&D Overview

- NFMCC R&D program has already led to many innovative accelerator concepts and approaches
  - driven by desire to solve challenging technical problems and perform critical particle physics experiments
- Examples

  Solenoidal pion capture from target
  RF phase rotation and bunching scheme
  Non scaling FFAG concept
  Muon cooling channels (linear, ring, helix)
  Theory of breakdown and conditioning in RF cavities
  High-pressure gas-filled cavities for cooling*
  Linear 6D helical cooling channel*
  Phase space manipulation techniques*
  High-field HTSC solenoids for giving low emittance*
  *Muons, Inc.

- Ongoing support of the NFMCC program (including SBIR component) will lead to continued innovation

Design and Simulations

- Simulations
  - a main focus in past year was participation in APS Multi-Divisional Neutrino Study (http://www.aps.org/neutrino/)
  - detailed report written by "Neutrino Factory and Beta Beams Experiments and Development Working Group"
    - http://www.aps.org/neutrino/loader.cfm?url=/commonspot/security/getfile.cfm&PageID=58766
    - considerable progress made in simplifying front-end systems while maintaining performance
  - making progress on studies of 6D cooling (emittance exchange) motivated by collider design
    - several cooling ring designs look workable
    - innovative helical "linear" channel also being investigated

Design and Simulations

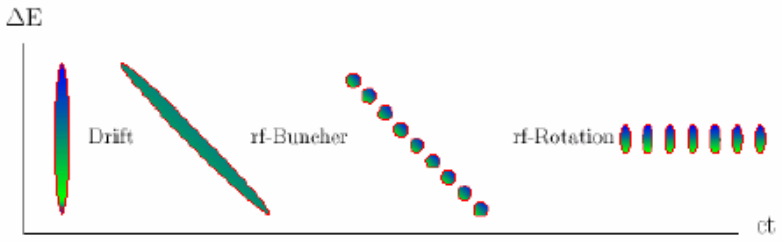
- Substantial cost savings predicted from reoptimization of Study II design
  - at the same throughput for one sign of muon as Study II
  - both signs now available, so facility performance effectively doubled

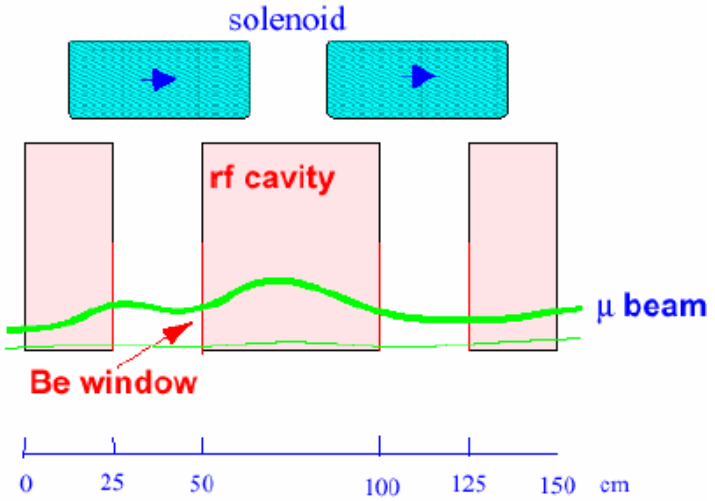
System	Cost reduction (Study IIa vs. II)
Target and Capture	0.99
Bunching and Phase Rotation	0.38
Cooling	0.60
Acceleration	0.77
Aggregate	0.65

  - main savings accrued from
    - developing RF bunching and phase rotation scheme
    - developing large acceptance FFAG scheme for final acceleration stages
    - simplifying cooling channel (takes advantage of larger downstream acceptance)

Design and Simulations

- Use RF to bunch, then to phase rotate
  - performance acceptable and less expensive than induction linacs
    - uses "standard" cooling channel components
    - keeps both μ^+ and μ^-
  - RF frequencies vary along the beam channel

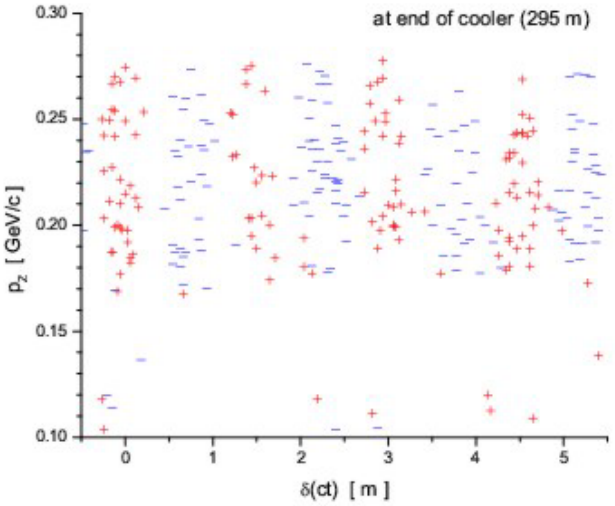


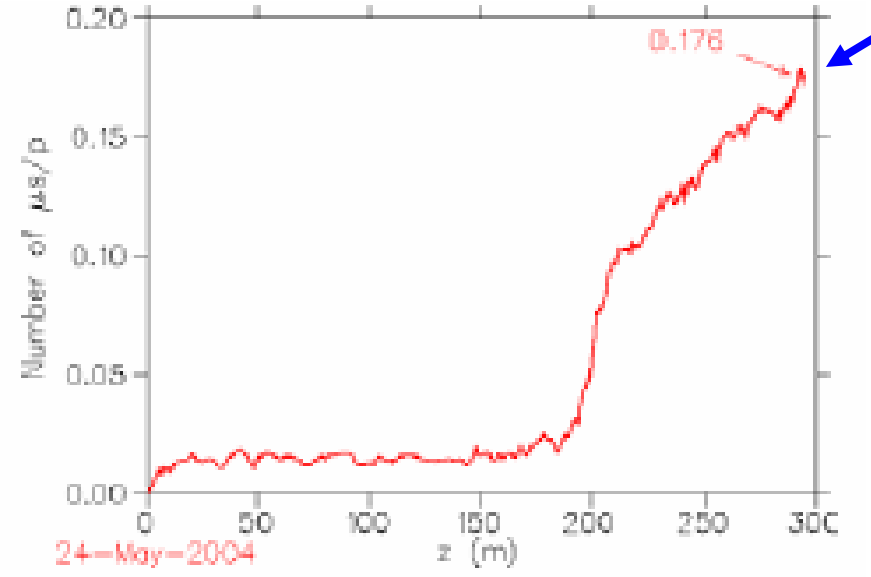


Design and Simulations

- Use simplified cooling channel
  - shorter, fewer magnets and cavities, simpler absorbers (replace LH_2 with LiH)
  - performs acceptably for both μ^+ and μ^- (with larger downstream acceptance)

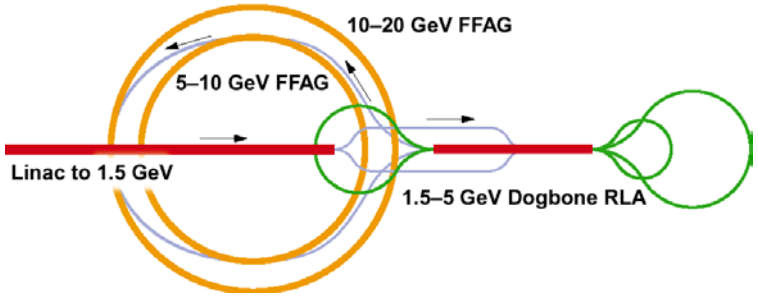
Same as Study II

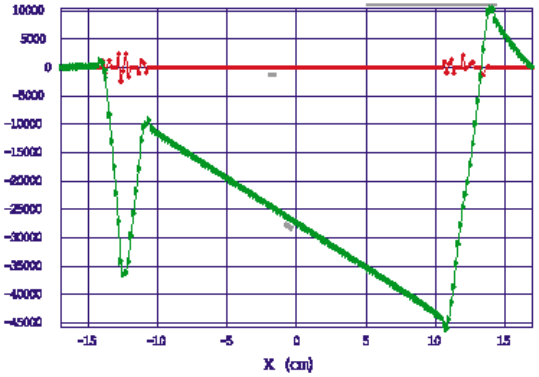


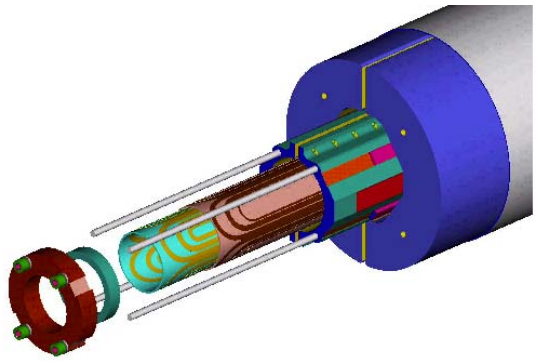


Design and Simulations

- Developed non-scaling FFAG scheme for cost-effective large acceptance acceleration
  - below 5 GeV, linac + RLA scheme looks more cost effective
  - required combined-function dipoles appear feasible and affordable
  - discussion of building an electron model of FFAG continues

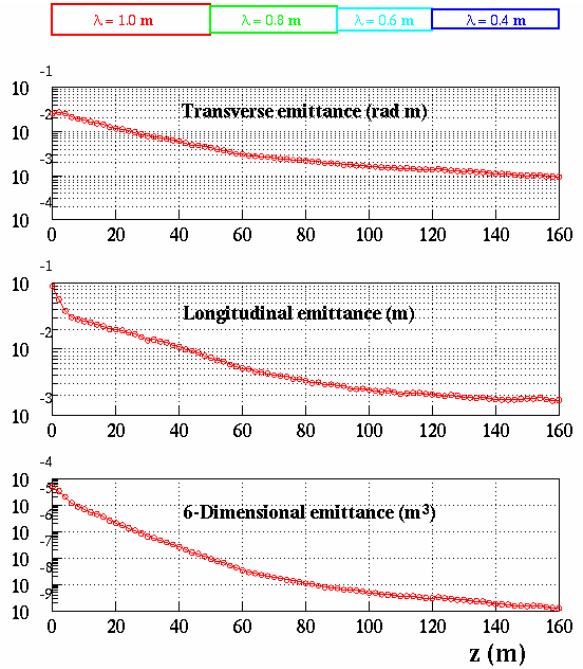






Design and Simulations

- Exploring innovative ideas for 6D cooling in Muon Collider (Muons, Inc.)



6D cooling factor ≈50,000 for 4 HCC stages

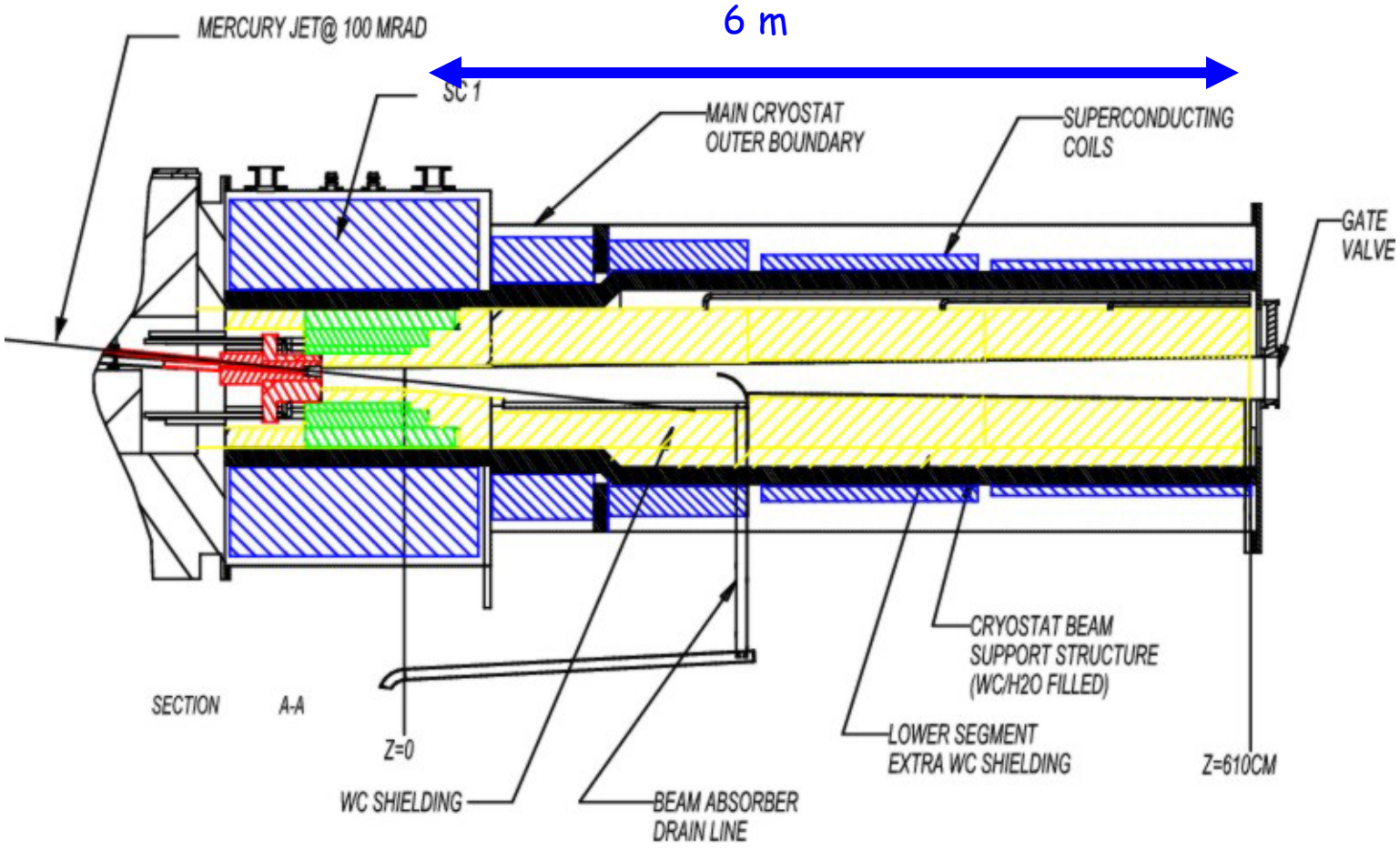
Final transverse emittance is 1 mm-rad

Siberian snake (analog to helical dipole)

- Helical cooling predicted to give 5x 6D cooling in 4 m channel
  - — could in principle be tested in MICE beam line
- Developing bunch coalescing technique (⇒ use NF bunch train for MC)
- This work supported via SBIR grants (covers 6 junior staff)

Targetry R&D

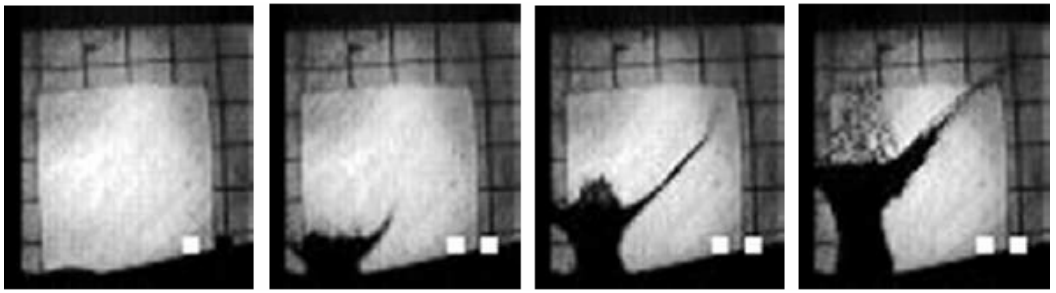
- Target concept based on free Hg jet in 20-T solenoidal field
  - jet velocity of 20 m/s establishes "new" target each beam pulse



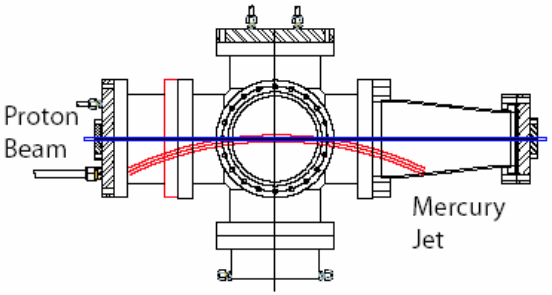
Targetry R&D

- Targetry effort focused mainly on validating efficacy of Hg-jet target
  - — **E951 experiment** looked at both stationary and moving Hg

Hg thimble



t = 0 0.5 1.6 3.4 ms



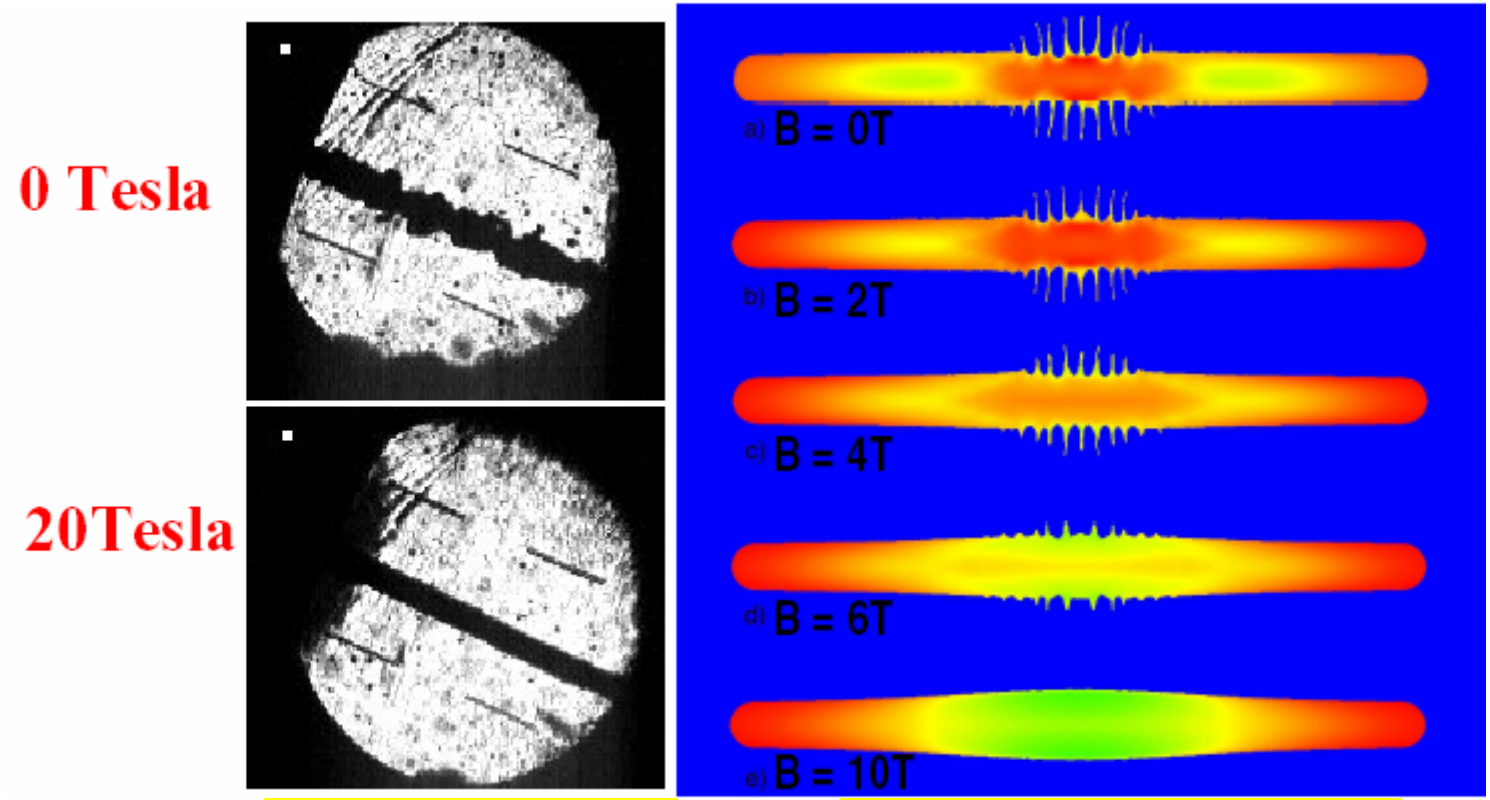
Hg jet

t = 0 0.75 2 7 18 ms

- Without magnetic field, Hg jet looks workable

Targetry R&D

- With magnetic field, surface instabilities are stabilized

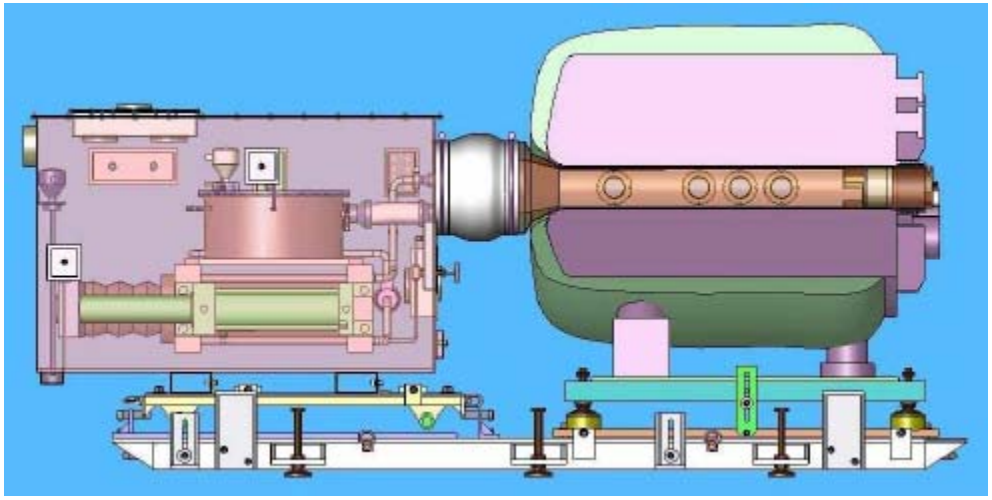


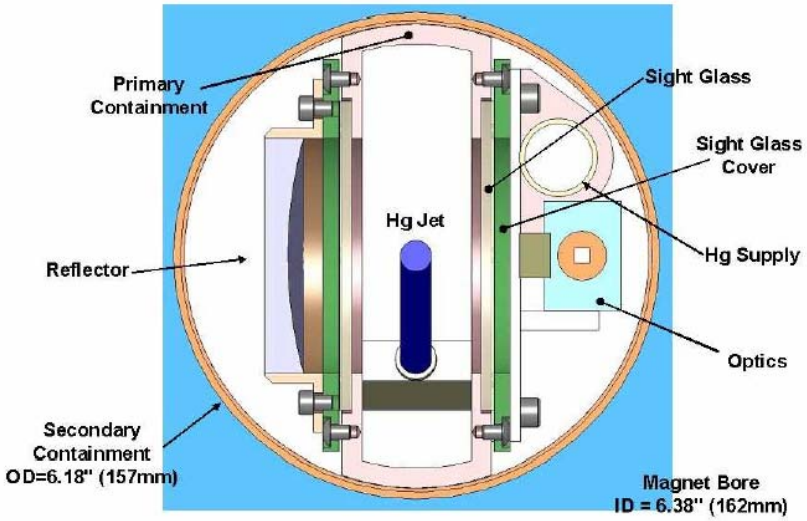
Experiment (Fabich)

MHD simulation (Samulyak)

Targetry R&D

- To do beam test of Hg jet with magnetic field, MERIT proposal submitted to CERN April, 2004 (approved April 2005)
  - located in TT2A tunnel to ISR, in nTOF beam line
  - first beam ~April, 2007

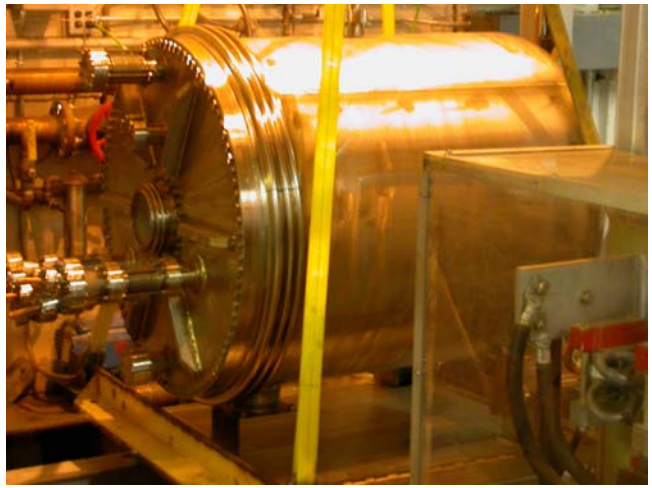




Targetry R&D

- Fabrication of 15 T magnet completed
  - operates at 80 K (cryogenic but not superconducting)
  - 8 MVA CERN power supply being refurbished to operate magnet
    - repetition rate ~ 0.001 Hz (20 minute cycle)

15-T solenoid in test location at MIT

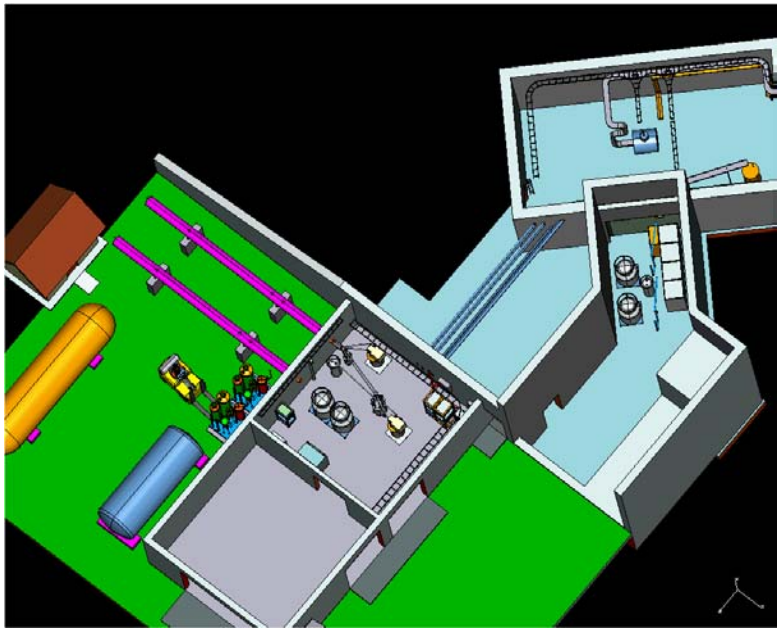


8 MVA power supply at CERN

- Components for Hg jet system for CERN target test experiment are being developed in collaboration with ORNL

Cavity R&D (MUCOOL)

- Cooling component tests (rf cavities and absorbers) carried out in newly constructed area at Fermilab
  - MUCOOL Test Area (MTA, funded by NFMCC)
    - located at end of 400 MeV linac; will ultimately be used for beam tests ("blast" tests)

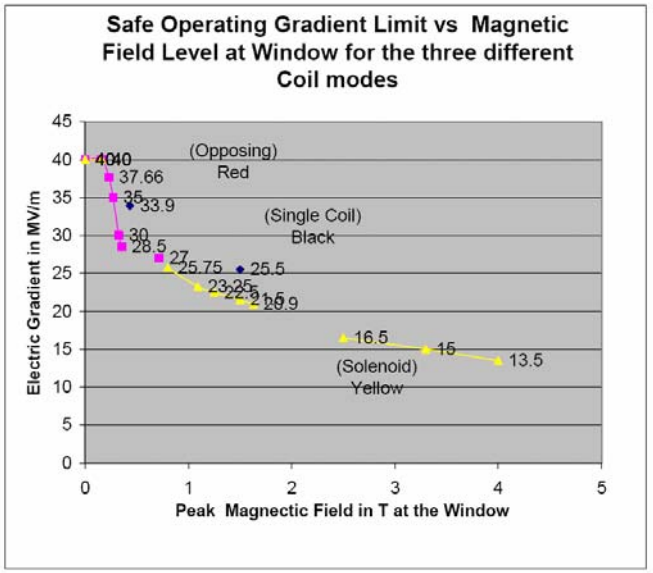


Cavity R&D (MUCOOL)

- **Motivation for RF test program: degradation in cavity performance observed when strong magnetic field is applied**

201 MHz cavity

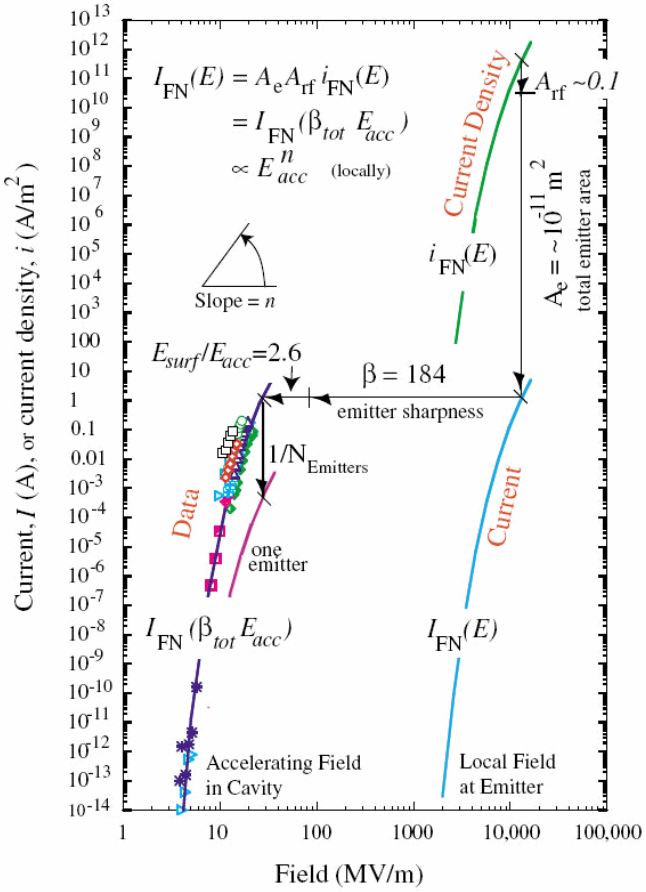
5-T solenoid +
805-MHz cavity



Cavity R&D (MUCOOL)

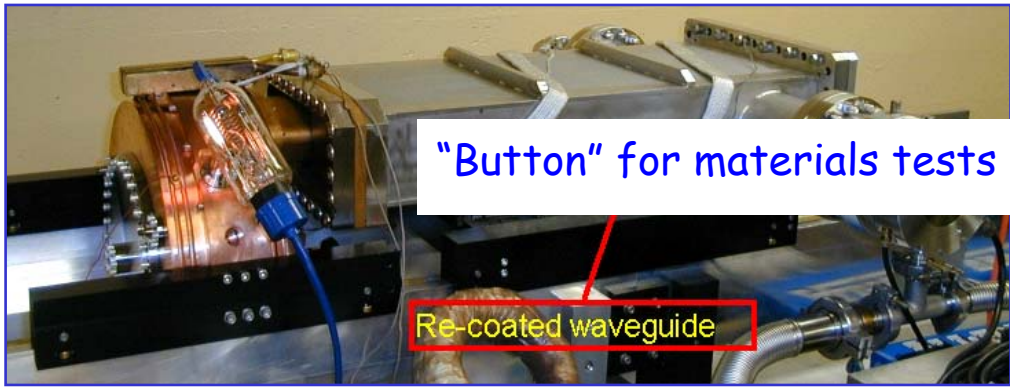
- **Working to develop insights into mechanism(s) of cavity breakdown**
  - **model (Norem) assumes breakdown when stress from surface field exceeds tensile strength of wall material ($E_{surf} \leq \sqrt{(2T/\varepsilon_o)/\beta_{eq}}$)**
    - **explains many aspects of high-field cavity operation**

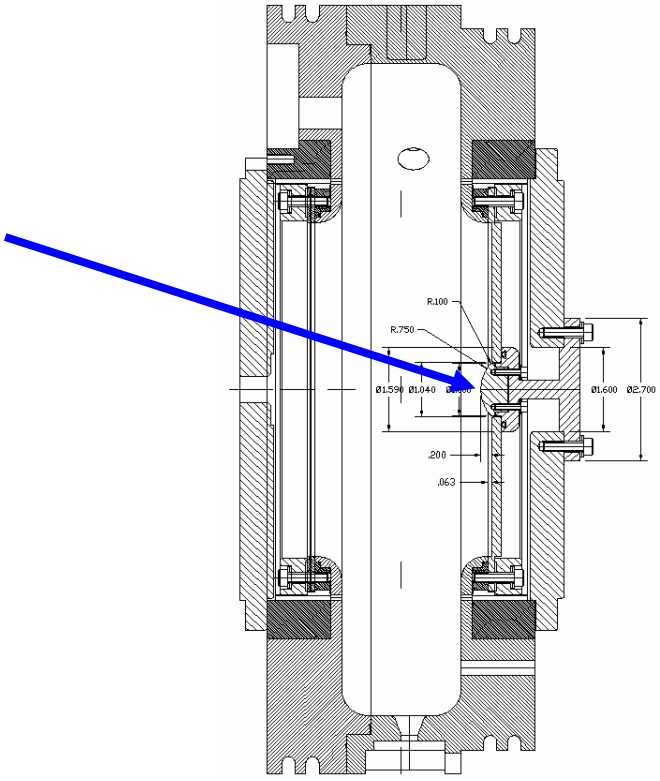
      breakdown rates as function of E and pulse length
      dependence on gas pressure
      dependence on solenoidal field
      dependence of E_{max} on pulse length and frequency
      "spitfests"
      conditioning process
  - **already several publications on this work, with a new one coming**
- **Model is relevant to other machines, e.g., linear colliders**



Cavity R&D (MUCOOL)

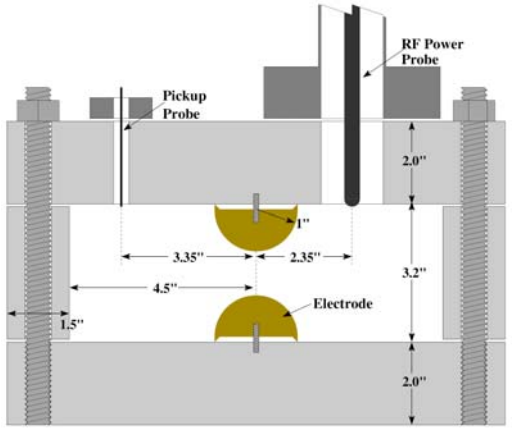
- Tests will use 805-MHz pillbox cavity with replaceable windows or "buttons"
  - cavity fits in bore of MTA solenoid
  - generate field enhancement at buttons to test performance of materials and/or coatings

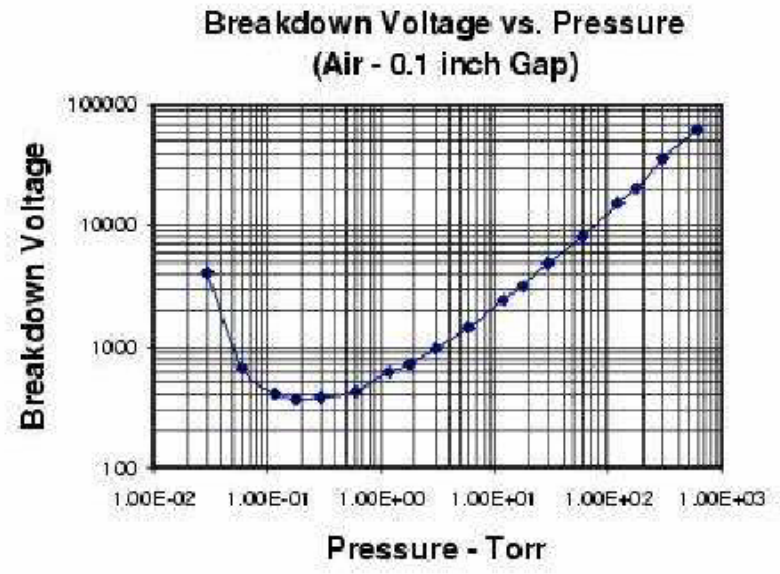


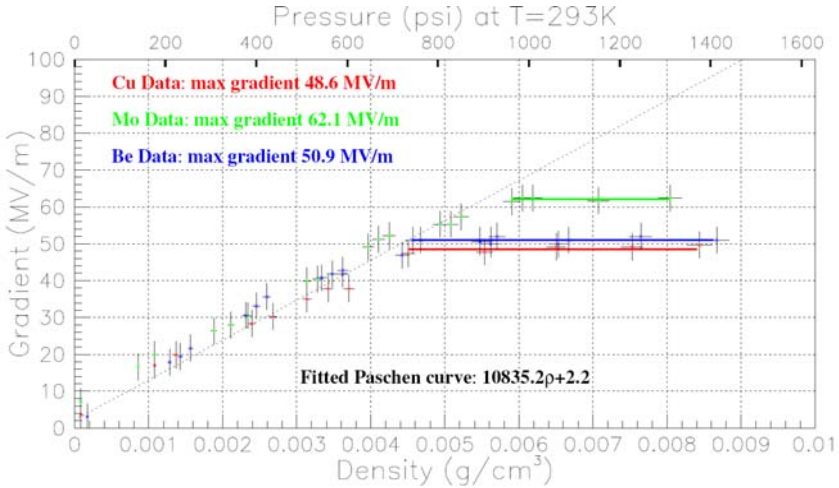


Cavity R&D (MUCOOL)

- Tested pressurized version of button cavity (Muons, Inc.)
  - use high pressure H_2 gas to limit breakdown

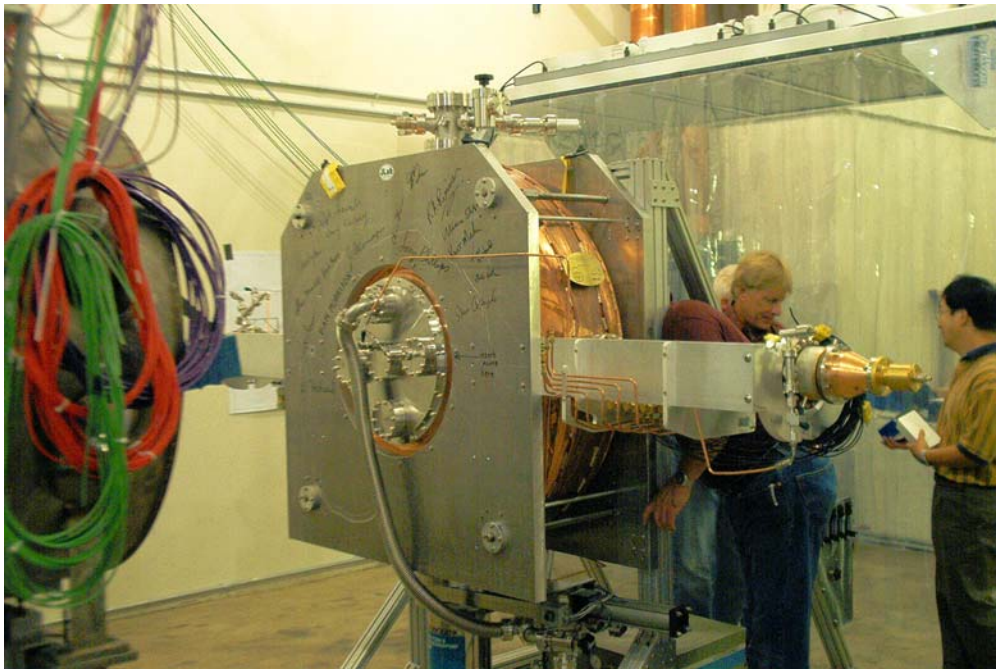


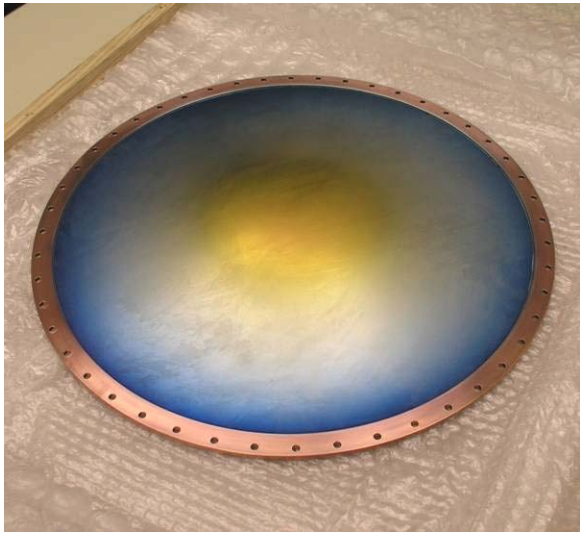




Cavity R&D (MUCOOL)

- Initial tests of 201 MHz cavity will commence
  - LBNL, Jlab, and U-Miss collaborated on cavity fabrication
    - cavity installed at MTA and awaiting power connection

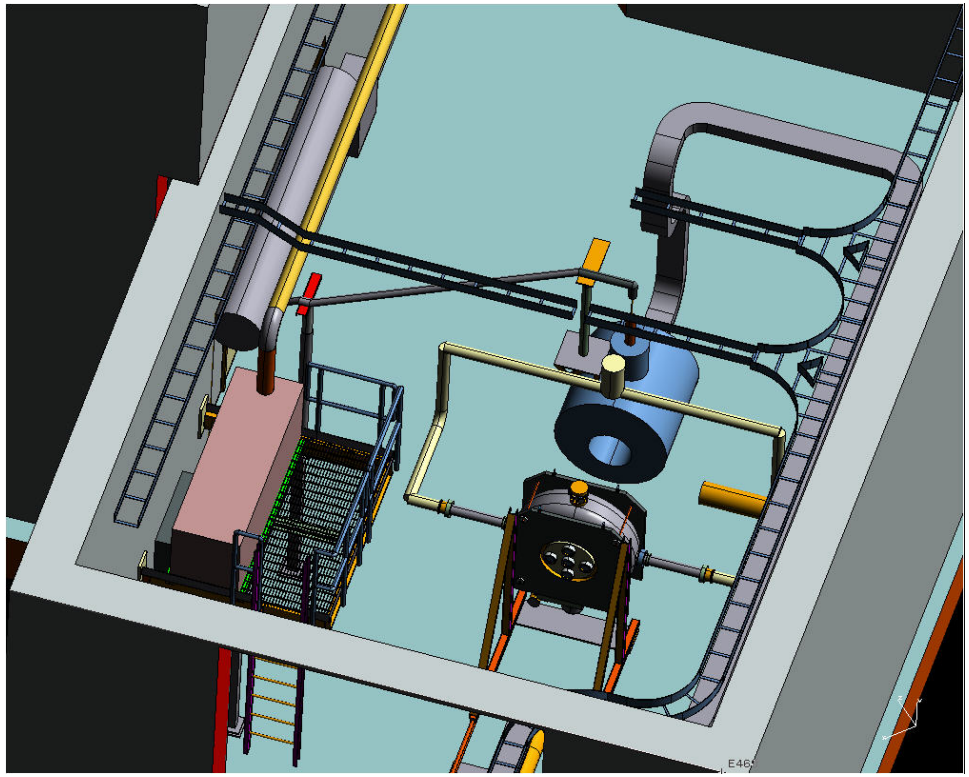




42-cm curved Be window

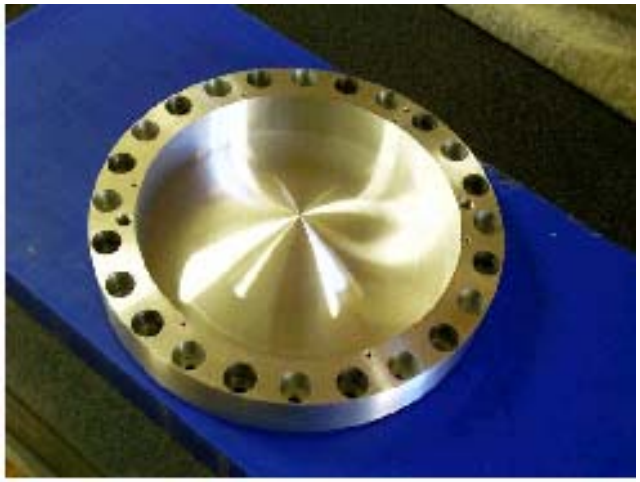
Cavity R&D (MUCOOL)

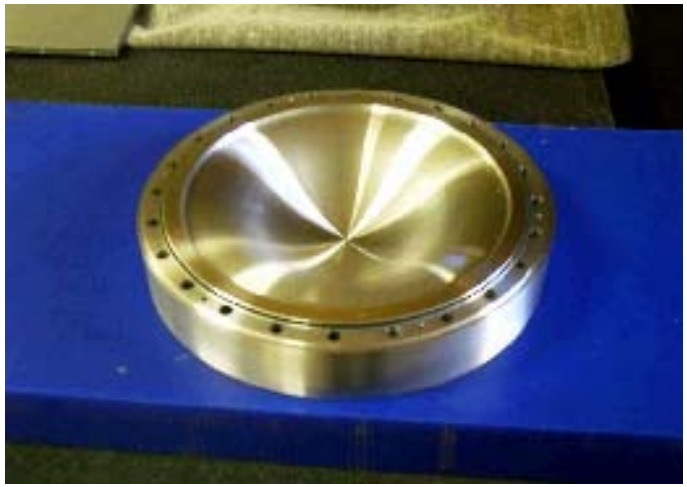
- 201-MHz cavity can be tested in close proximity to 5-T solenoid to provide some magnetic field
  - more realistic field configuration requires large diameter coupling coil (awaiting sufficient funding to acquire this)



Absorber R&D (MUCOOL)

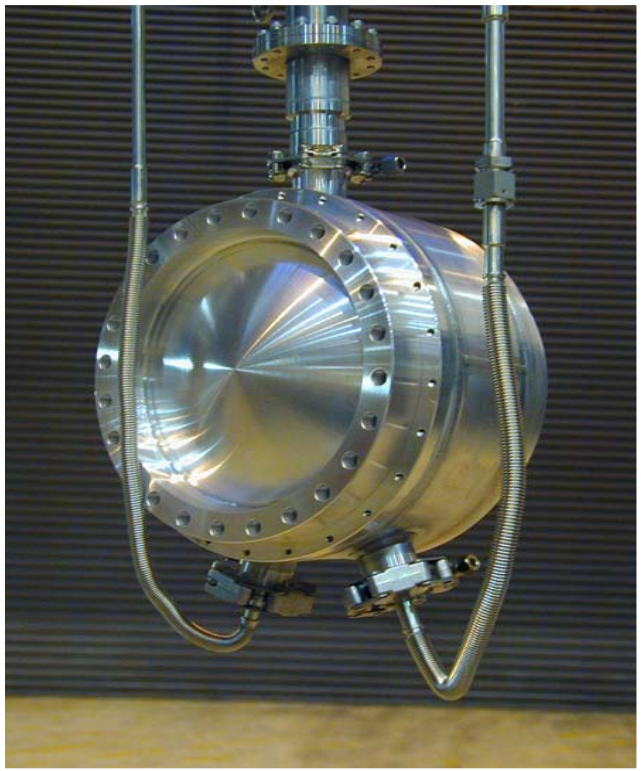
- Absorber group (IIT, NIU, Oxford) has developed strong, thin windows
  - new stronger (⇒thinner) design built (at U.-Miss.) and tested successfully at Fermilab
    - 125 μm window is 3x stronger than original design
    - burst at 140 psi





Absorber R&D (MUCOOL)

- Initial absorber LH_2 filling tests carried out at MTA last summer
  - convection-cooled absorber prototype fabricated at KEK
  - plan to also test IIT/Fermilab forced-flow absorber design here

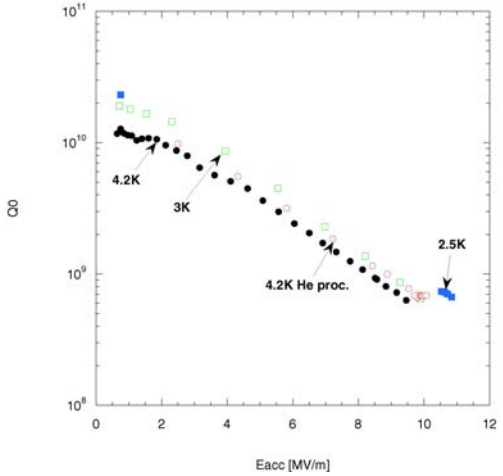


Prototype LH_2 absorber

Test cryostat at MTA

SCRF R&D

- Initial test of 201-MHz scrf cavity at Cornell gave 11 MV/m
  - *Q* slope unacceptably large
- Work on 201 MHz scrf for acceleration system has shifted gears (but funding uncertain)
  - now trying to understand *Q* slope in terms of impurities and Nb coating properties



- Building 500 MHz cavity to study Nb sputtering techniques
  - can study phenomena more cost-effectively with smaller cavity

MICE

Muon Ionization Cooling Experiment

Aims: demonstrate feasibility and performance of a section of cooling channel

Main challenges:
RF in magnetic field!
10^{-3} meas. of emittance
Safety issues

Final PID:
TOF
Cherenkov
Calorimeter

4T spectrometer II

Status:
Approved at RAL(UK)
First beam: 04-2007
Funded in: UK,CH,JP,NL,US
Requests: Be,CH,It,JP,US

Cooling cell (~10%)
β=5-45 cm, liquid H_2, RF

4 T spectrometer I

TOF

Single-μ beam
~200 MeV/c

Some prototyping:

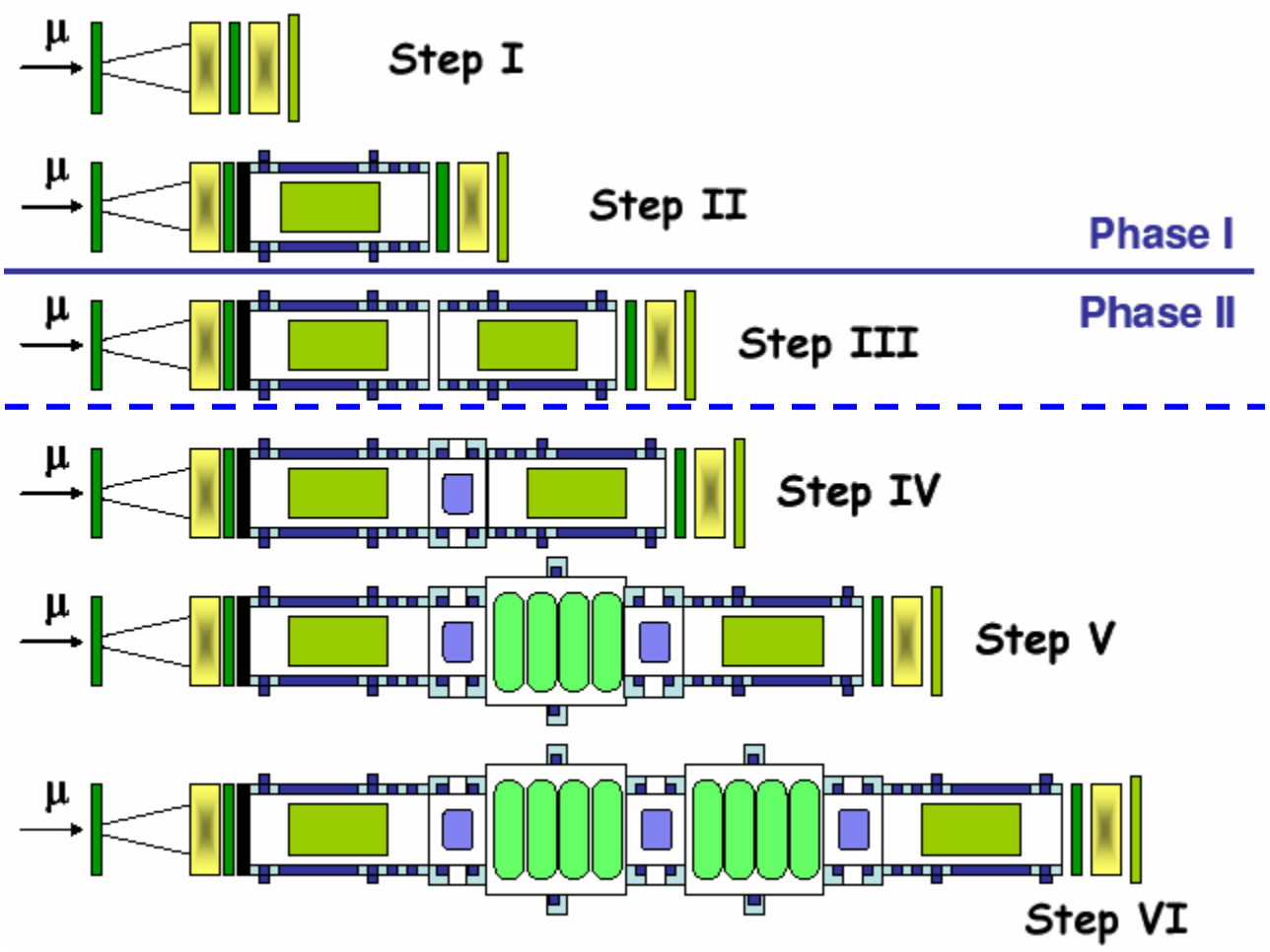
Scintillating-fiber tracker

MUCOOL Liquid-hydrogen absorber

MUCOOL 201 MHz RF cavity with beryllium windows

MICE

- **MICE** cooling channel will be built up in stages to ensure complete understanding and control of systematic errors



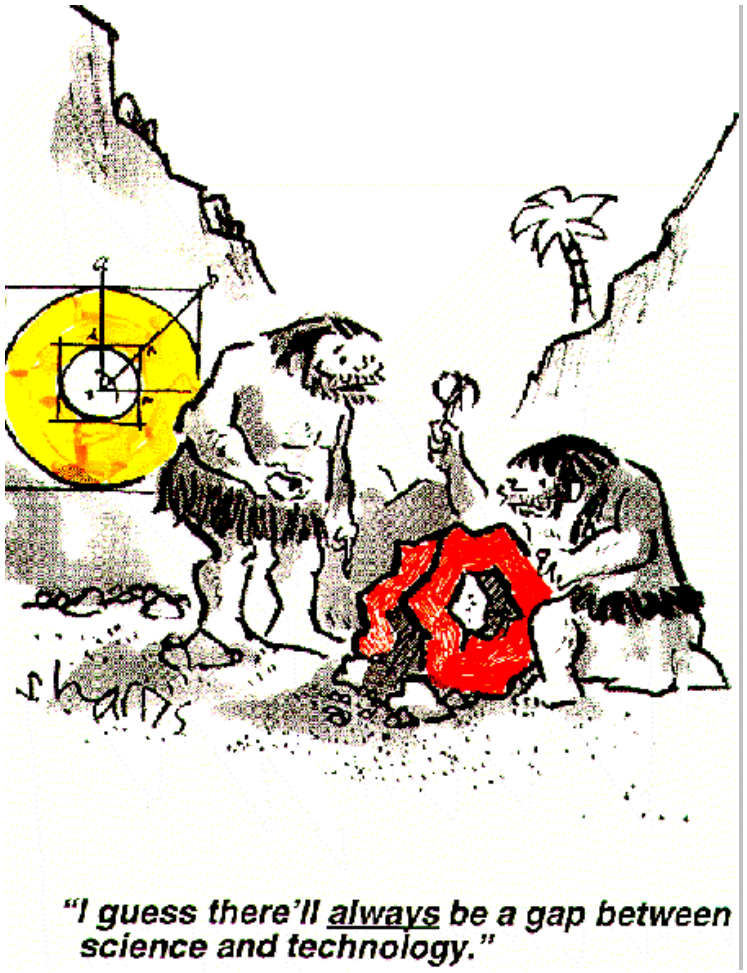
Future Plans

- Targetry
  - complete MERIT experiment and publish results
- Cooling/MICE
  - complete testing of 805 MHz and 201 MHz high-gradient cavities
  - complete MICE experiment and publish results
- Acceleration
  - study *Q* disease and develop mitigation techniques
- Simulations
  - continue developing cost-optimized front-end for Neutrino Factory
  - identify Proton Driver requirements from Neutrino Factory application
  - participate in upcoming World Design Study (follow-on to ISS)
  - continue collider studies with aim of completing feasibility study

Summary and Outlook

- NFMCC has made excellent progress in identifying and studying the R&D topics relevant to design of muon-based NF and collider
  - both driven by strong science case
- Solid R&D management and planning processes are in place to ensure that activities are well-focused and effective
  - internal audits by PM; external audits by MUTAC/MCOG
- Close interactions with corresponding groups in Europe and Japan serve to minimize duplication of effort and maximize R&D effectiveness
  - examples: MICE, MERIT, ISS, NuFact workshops
- NFMCC fosters close collaboration between accelerator and particle physicists, including training of students and post-docs
- NFMCC program integral to the "big picture" laid out in *The Neutrino Matrix* report (APS Multi-Divisional Study)
  - strong endorsement of NFMCC R&D program will greatly help in securing additional funds to accomplish goals in a timely manner

Final Thought



"I guess there'll always be a gap between science and technology."

Appendix

- **Organization details (see http://www.cap.bnl.gov/mumu/mu_home_page.html)**

Muon Collaboration Oversight Group (MCOG)

S. Aronson	BNL
S. Holmes	FNAL (contact)
J. Siegrist	LBNL

NFMCC Management

S. Geer (FNAL), Co-spokesperson
R. Palmer (BNL), Co-spokesperson

M. Zisman (LBNL), Project Manager

Muon Technical Advisory Committee (MUTAC)

H. Edwards	FNAL (Outgoing Chair)
R. Kephart	FNAL (Incoming Chair)
C. Adolphsen	SLAC
M. Breidenbach	SLAC
G. Dugan	Cornell
R. Garoby	CERN
M. Harrison	BNL
J. Hastings	SLAC
S. Henderson	ORNL
M. Lindner	TU-Munich
K. Yokoya	KEK

Next MUTAC review: March 16–17, 2006 at Fermilab

Appendix

- **Membership in MC Executive and Technical Boards (see http://www.cap.bnl.gov/mumu/mu_home_page.html)**

Executive Board

S. Geer	(FNAL)	Co-Spokesperson
R. Palmer	(BNL)	Co-Spokesperson
A. Sessler	(LBNL)	Associate Spokesperson
M. Tigner	(Cornell)	Associate Spokesperson
D. Cline	(UCLA)	
D. Errede	(UIUC)	
G. Hanson	(UC-Riverside)	
D. Kaplan	(IIT)	
K. McDonald	(Princeton)	
A. Skrinsky	(BINP-Novosibirsk)	
D. Summers	(U.-Mississippi)	
A. Tollestrup	(FNAL)	
W. Weng	(BNL)	
J. Wurtele	(UC-Berkeley)	
M. Zisman	(LBNL)	Project Manager
J. Gallardo	(BNL)	Secretary

Technical Board

S. Geer	(FNAL)	Co-Spokesperson
R. Palmer	(BNL)	Co-Spokesperson
A. Bross	(FNAL)	MUCOOL
M. Green	(LBNL)	
D. Hartill	(Cornell)	
H. Kirk	(BNL)	
D. Kaplan	(IIT)	MICE
K. McDonald	(Princeton)	Targetry
J. Norem	(ANL)	
R. Fernow	(BNL)	Simulations
R. Rimmer	(Jlab)	
M. Zisman	(LBNL)	Project Manager

Appendix

- European "MCOG": EMCOG

  CERN: Carlo Wyss (Chair), John Ellis, Helmut Haseroth
  CEA: Pascal Debu, François Pierre
  IN2P3: Jean-Eric Compagne, Jacques Dumarchez, Stavros Katzanevas
  INFN: Marco Napolitano (Napoli), Andrea Pisent (Legnaro)
  GSI: Oliver Boine-Frankenheim, Ingo Hofmann
  Geneva: Alain Blondel (Secretary)
  PPARC: Ken Long
  PSI: Albin Wrulich
  RAL: Rob Edgecock, Ken Peach

  — comment on MICE

  "Cooling is on the critical path for a neutrino factory; there is a consensus that a cooling experiment is a necessity."

  — comments on MERIT

  "Locating this experiment at CERN would certainly encourage participation from European collaborators.

  The experiment seems able to achieve its very important goal, and is therefore highly recommendable. Several clever solutions are envisaged."

Appendix

- **Recent European recommendations**

SPSC (October, 2004): *"CERN should arrange a budget and personnel to enhance its participation in further developing the physics case and the technologies necessary for the realization of such [neutrino] facilities. This would allow CERN to play a significant role in such projects wherever they are sited."*

SPC to CERN Council (December, 2004): *"Future neutrino facilities offer great promise for fundamental discoveries. CERN should join the world effort in developing technologies for new facilities: Beta beams, Neutrino Factory…wherever they are sited.*

Focus now on enabling CERN to do the best choice by 2010 on future physics programme."

- **CERN Council set up Strategy Group on future plans in Europe**
  - **report due in July 2006**

Appendix

- **FY06 NFMCC budget (only DOE-NFMCC funds)†**

Institution	COOLING /MICE	TARGETRY	ACCEL./ COLLIDER	RESERVE	TOTAL ($K)
BNL		405			405
FNAL	45				45
LBNL[a]	680			70	750
ANL	150				150
IIT	85				85
Mississippi	20	25	20		65
Princeton		105			105
UCLA	25		45		70
UC-Riverside			20		20
ORNL		95			95
Jlab	5		5		10
TOTAL ($K)	**1010**	**630**	**90**	**70**	**1800**

[a]Includes MICE funding of $620K.

†**Also: salary support from BNL, FNAL, LBNL; support from NSF of $0.1M + $0.75M MRI grant; support of Muons, Inc. via SBIR grants**

Appendix

- **Supplemental request submitted to DOE in January 2006 (priority order)**
  - **priorities decided in discussions between Spokespersons and PM**

Item	Request ($K)
1) Coupling coil design and construction	975
2) MICE design, commissioning, operation, analysis	350
3) ISS travel support	50
TOTAL	1375

Appendix

- **Comments from April '04 MUTAC report**

"The Muon Collaboration continues to make significant progress, but with very constrained M&S funding. As last year, 1M$ more would make a significant impact. This is especially true in light of the questionable ICAR funds, and the opportunity to do the CERN target experiment."

"...US support on MICE is important for the international preparation to proceed. Approval of the US MICE proposal would have significant positive impact on the Muon Collaboration and its ability to develop hardware."

"The Committee notes the significant progress achieved in establishing a worldwide collaboration and the integration of the various R&D programs. In particular Japanese participation has increased in many areas such as MuCool, MICE, targetry, FFAG and NuFact workshops. The MICE proposal is an example of the effective operation of this larger collaboration."

Appendix

- **Comments from April '05 MUTAC report**

"The activities pursued today are clearly focused on the most important subjects determining the feasibility of a neutrino factory, relying on—and contributing to—the MICE experiment at RAL (UK) and the nTOF11 experiment at CERN."

"There is the potential that the Muon Collaboration efforts would enable significant physics opportunities. Readiness to exploit these opportunities requires completion of a variety of proof of concept R&D tasks. MC is focused to carry out these tasks."

"We note that muon accelerators (factories or colliders) are one of the very few HEP future accelerator ideas on the horizon, that R&D to develop these ideas and provide proof of principle takes years of consistent effort and support, and that major collaborative efforts and international commitments must have consistent support."

"The MC has been exemplary in its drawing of collaborators from a wide diversity of HE physicists in the muon acceleration futuristic concepts."

Note: "nTOF11" ⇒ MERIT

Appendix

- **MCOG FY04 comments**

"MUTAC and MCOG note the continuing successes in the muon R&D work accomplished during the past year, especially the technical creativity shown in Neutrino Factory conceptual designs utilizing FFAG machine concepts for accelerating muons, as well as the significant progress in establishing worldwide collaboration in the study of important technical R&D topics. We are particularly pleased with the continuing progress by university-based groups in advancing some of the important machine R&D topics associated with cooling and the Muons, Inc. conceptual work on high-pressure, cold hydrogen gas forming an absorber mass inside a normal rf cavity to provide an integrated muon cooling environment. This progress has occurred in spite of four successive years of severe budget decreases that have strongly restricted the scope of experimental R&D work able to be carried out by the Muon Collaboration."

"...MCOG accepts and endorses the MUTAC Report attached here and urges the DOE to seek ways of supplementing R&D funding for the Muon Collaboration. An additional amount of $1M or more, per year, would provide important relief to the program and improve the rate of advance in the technical areas of study. We urge the DOE to consider such an increase in funding as they prepare future budgets for the muon R&D program."

Appendix

- **MCOG FY05 comments**

"MCOG recommends that the U.S. continue its active participation in the MICE collaboration: this is the most ambitious program for demonstrating a practical implementation of muon cooling in a full experimental context."

"MCOG strongly supports the NFMCC efforts to carry out the high intensity target tests on a liquid mercury target currently approved at CERN."

"MCOG recommends strong participation of the NFMCC within the World Design Study, which represents the next iteration of the "Feasibility Study" series conducted within the U.S. over the last several years."

"MCOG recommends that DOE consider providing additional funding, at a level of $0.4M or more per year, to provide important flexibility within the program and increased confidence that technical milestones can be met on a reasonable time scale."

"World Design Study" morphed into International Scoping Study